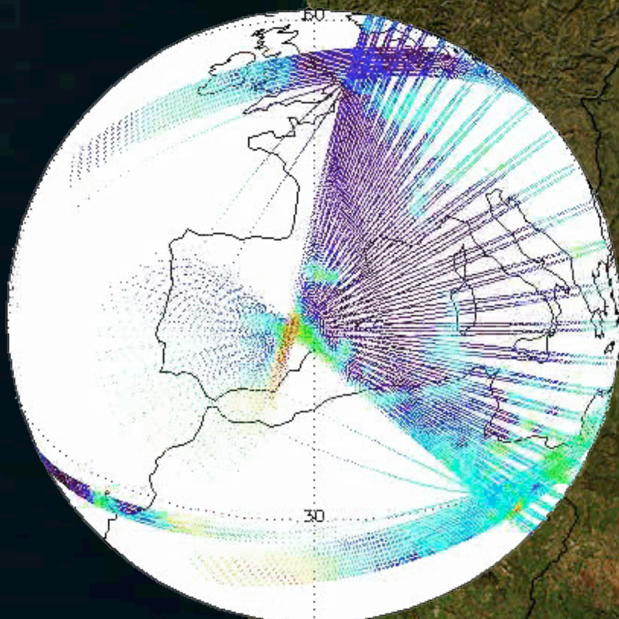
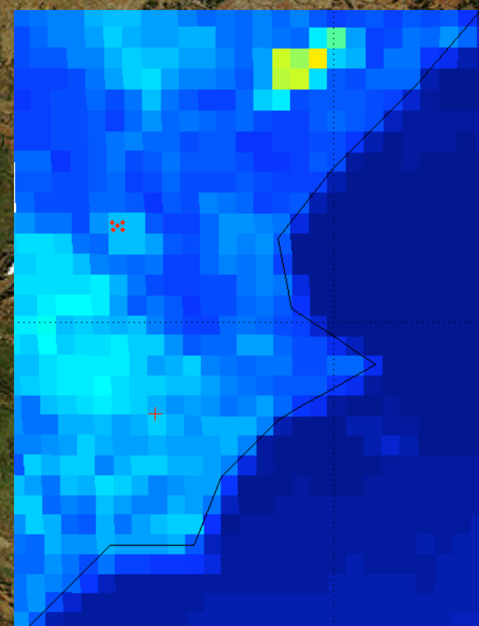
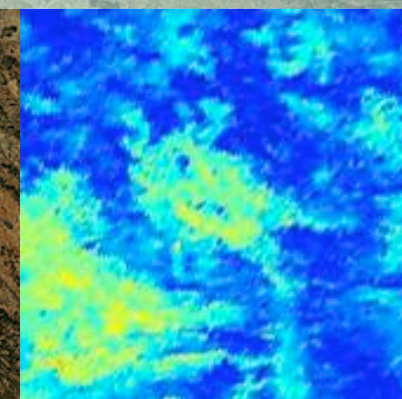
# Use of PSF-weighted MODIS Bidirectional Reflectances for the Validation of GERB/CERES TOA Radiances and Fluxes over the Valencia Anchor Station area





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8th CERES-II Science Team Meeting

# Outline

1. Objectives
2. Background
3. Methodologies
4. Results
5. Conclusions

# 1. Objectives

The purpose of this work is to improve the methodology already developed to compare measured TOA radiances and derived fluxes to independent radiative transfer (RT) simulations.

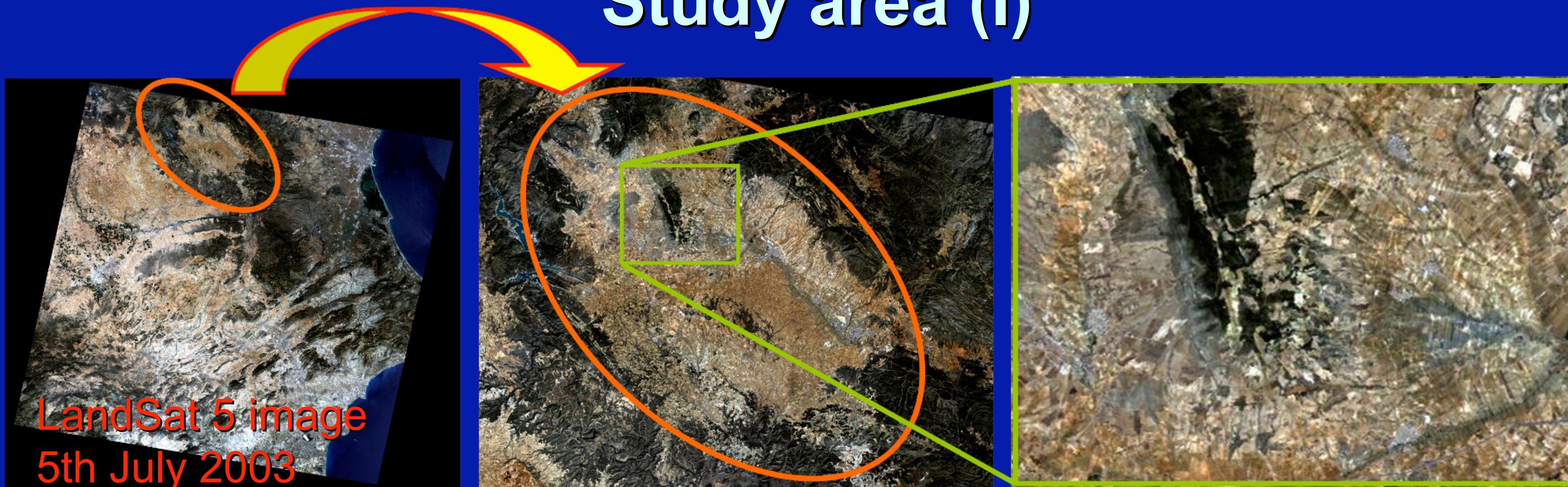
The RT simulations are performed using surface and atmospheric measured parameters collected during the *GERB/CERES Ground Validation Campaigns* at the *Valencia Anchor Station* (VAS) area in February 2004 and in July-August 2006, as well as Bidirectional Reflectances derived from MODIS MOD43 BRDF product for the study area.

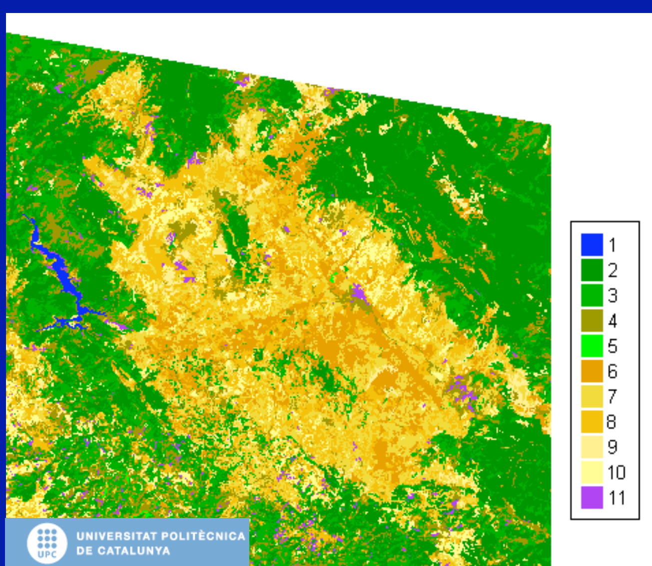
The methodology is applied to the NASA *Clouds and the Earth's Radiant Energy System* (CERES) PAPS (Programmable Azimuth Plane Scanning) data in the framework of the SCALES project (*SEVIRI and GERB Cal/Val Area for Large scale field ExperimentS), and it is being applied to* validate GERB data over the VAS area.

The study includes the selection of atmospheric profiles from on-purpose radiosonde and GPS data, a BRDF (*Bidirectional Reflectance Distribution Function*) estimation for the large-scale study area in Winter Season, BRDFs calculations for every single CERES footprint and GERB pixels from MODIS data and *Streamer* RT simulations of TOA SW and LW radiances and fluxes.

# 2. Background

## Study area (I)




**Land Use Classification**

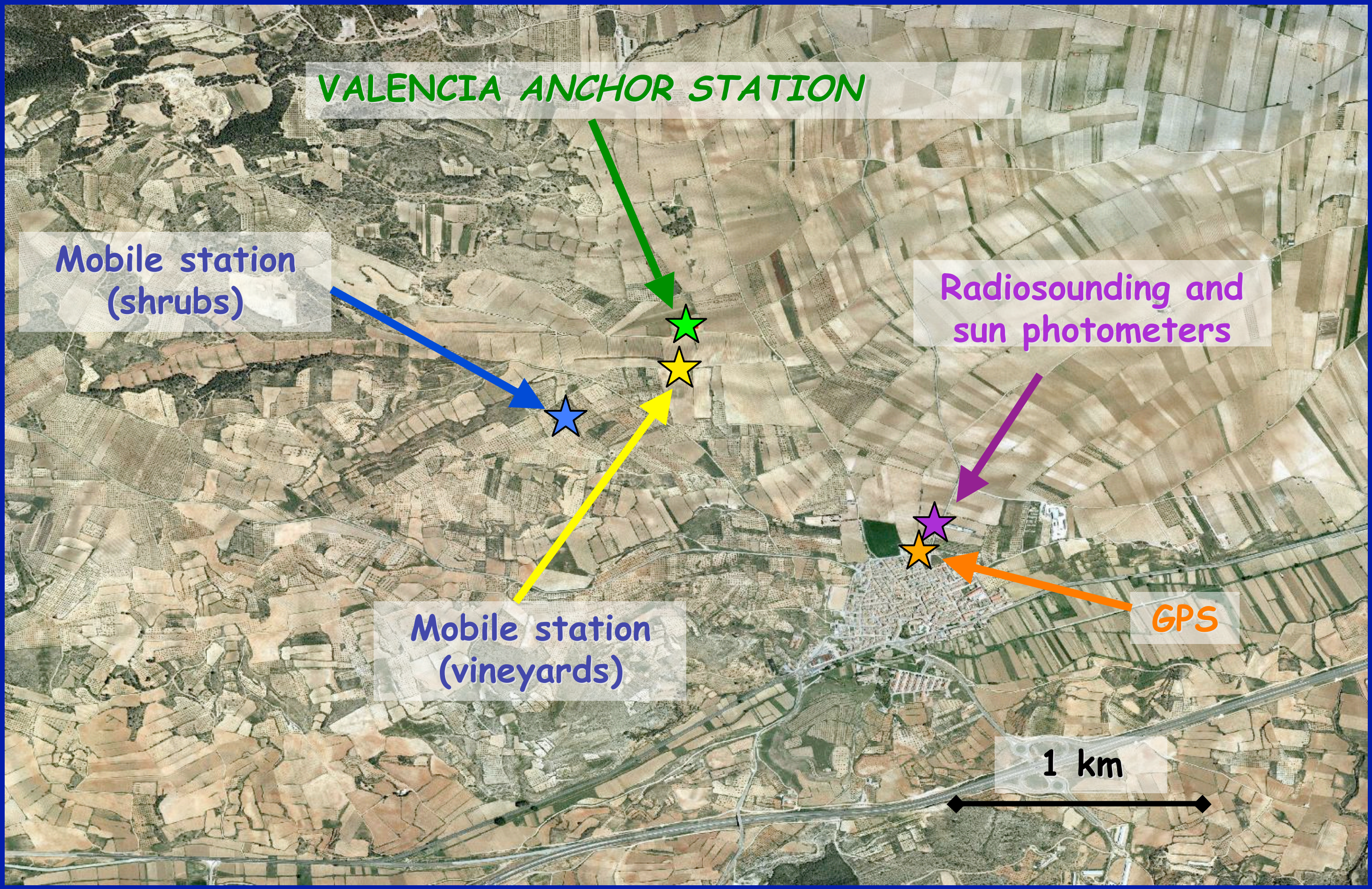
1: water
2: pine trees
3: low density pine trees and shrubs
4: shrubs
5: irrigated crops
6: vineyards
7: low density vineyards
8: very low density vineyards
9: herbal crops
10: bare soil
11: urban areas

# Study area (II)

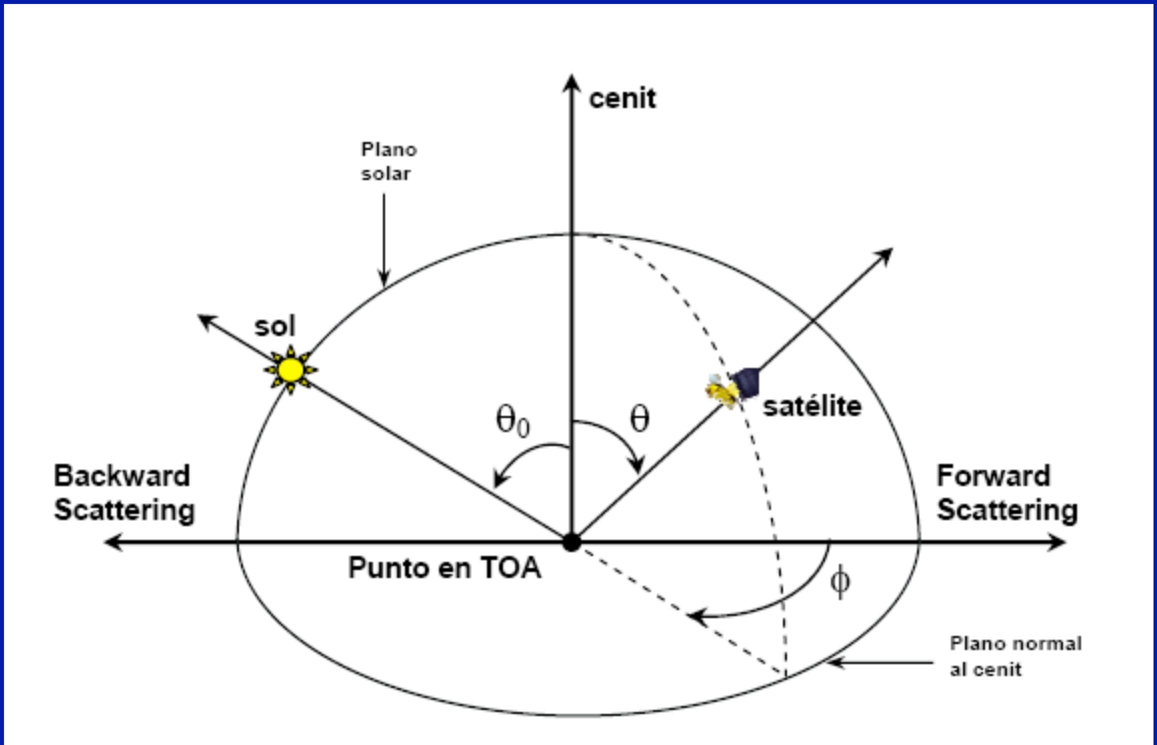
Ground Validation Campaign
February 2004

June 2003

# Instruments distribution during the Campaigns.



# Observation Geometry



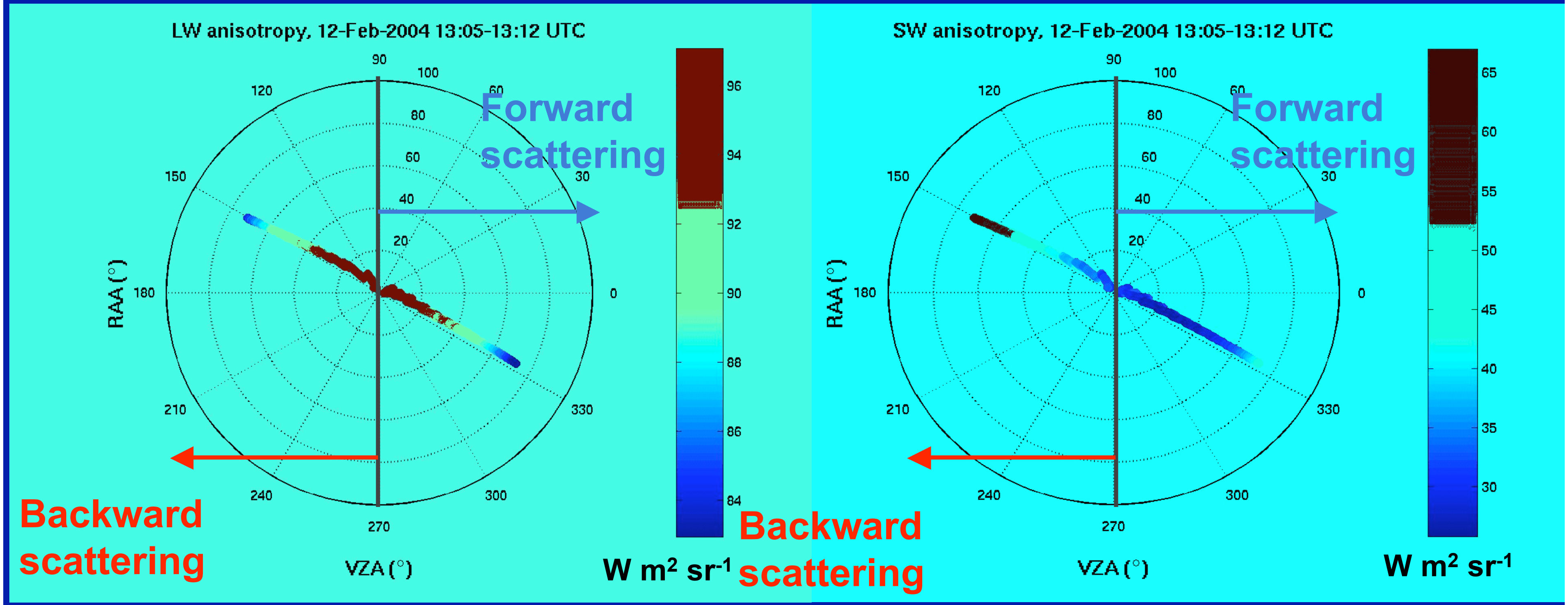

$\theta_0$ stands for Solar Zenith Angle (SZA)

$\theta$ stands for Viewing Zenith Angle (VZA)

$\phi$ stands fo Relative Azimuth Angle (RAA)

# CERES TOA radiances over the study area (I)

**12 FEB 2004**



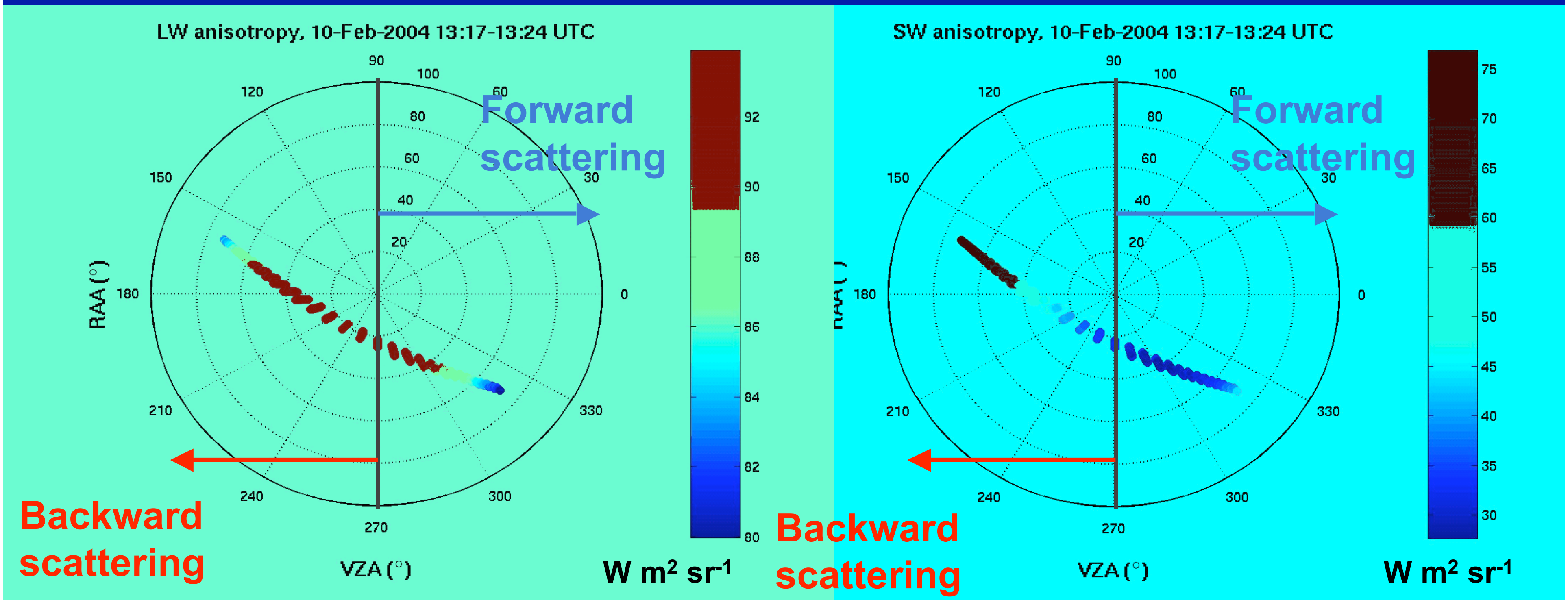

CERES data used:

SSF CERES-MODIS FM2 Edition 2B

SSF CERES-MODIS FM3 Edition 1B

# CERES TOA radiances over the study area (II)

**10 FEB 2004**



# 3. Methodology

## Parameter selection

### Atmospheric profiles

- **Water vapour, pressure and temperature**

Radiosounding water vapour scaled to the GPS IWV.

- **Ozone profile**

Streamer MLW profile scaled to TOMS *(Total Ozone Mapping Spectrometer) value*

- **Aerosols profile**

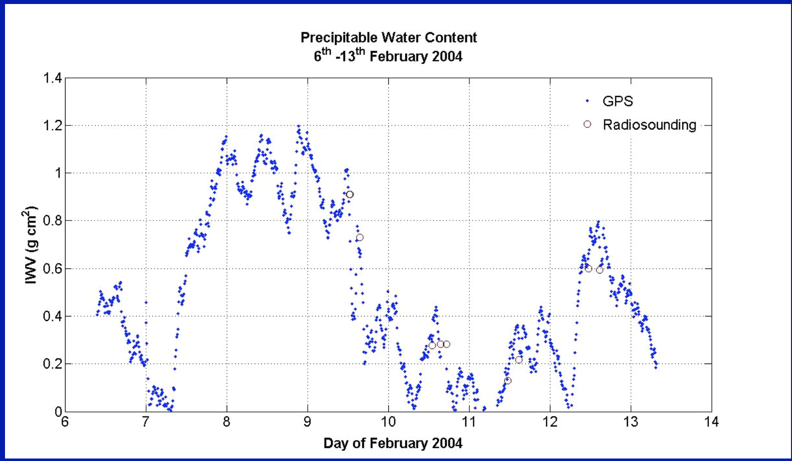
Streamer MLW profile + sun photometer (EKO and CE-318 CIMEL) measurements + assume background tropospheric aerosols and background stratospheric aerosols.

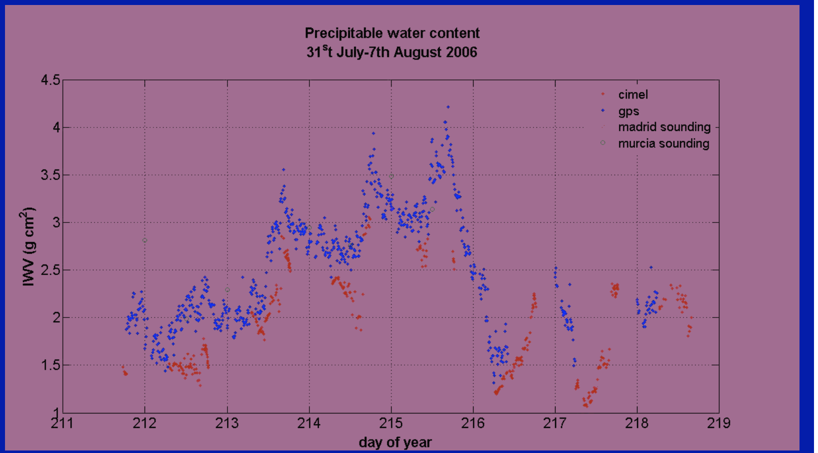
### Surface emissivity

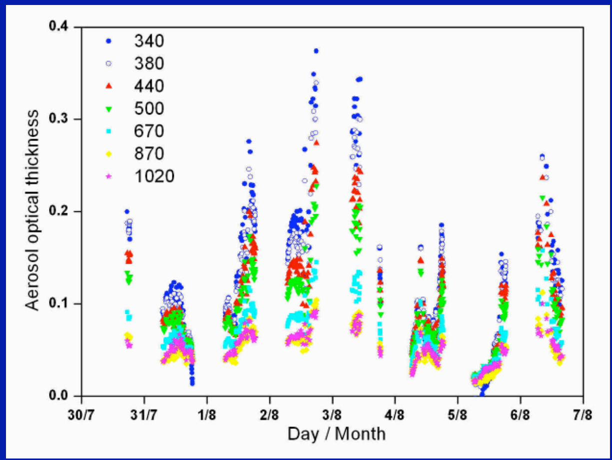
From CERES/SARB data

### Surface temperature

Measured temperatures at the VAS and the mobile station



# BRDF *(Bidirectional Reflectance Distribution Function)*

**TOA radiances are sensitive to the anisotropy of the surface reflectivity and its diurnal changes.**

- **1) Method based on surface observations**

**BRDF: obtained from the broadband albedo measured at the VAS and the mobile station,($a_0^{BB}$), JHU spectral albedo ($a_\lambda^{JPU}$) and Ahmad & Deering bidirectional reflectances of bare soil ($\rho_\lambda(\theta_0, \theta, \phi)$)**

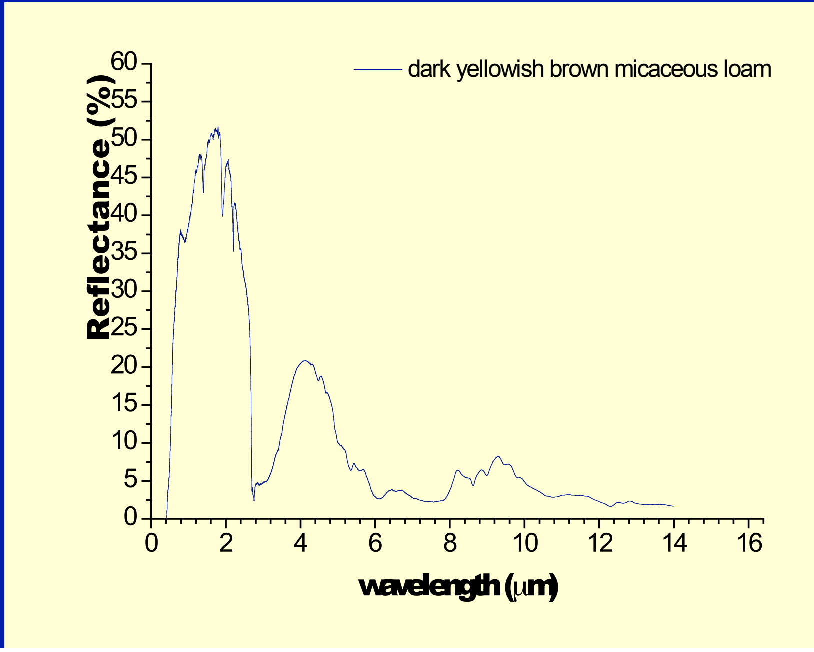
- **1. scale the JHU spectral albedo**

$$a'_\lambda = \frac{a_\lambda^{JHU}}{\int_{\lambda_2}^{\lambda_1} a_\lambda^{JHU} d\lambda} a_{BB}^0$$

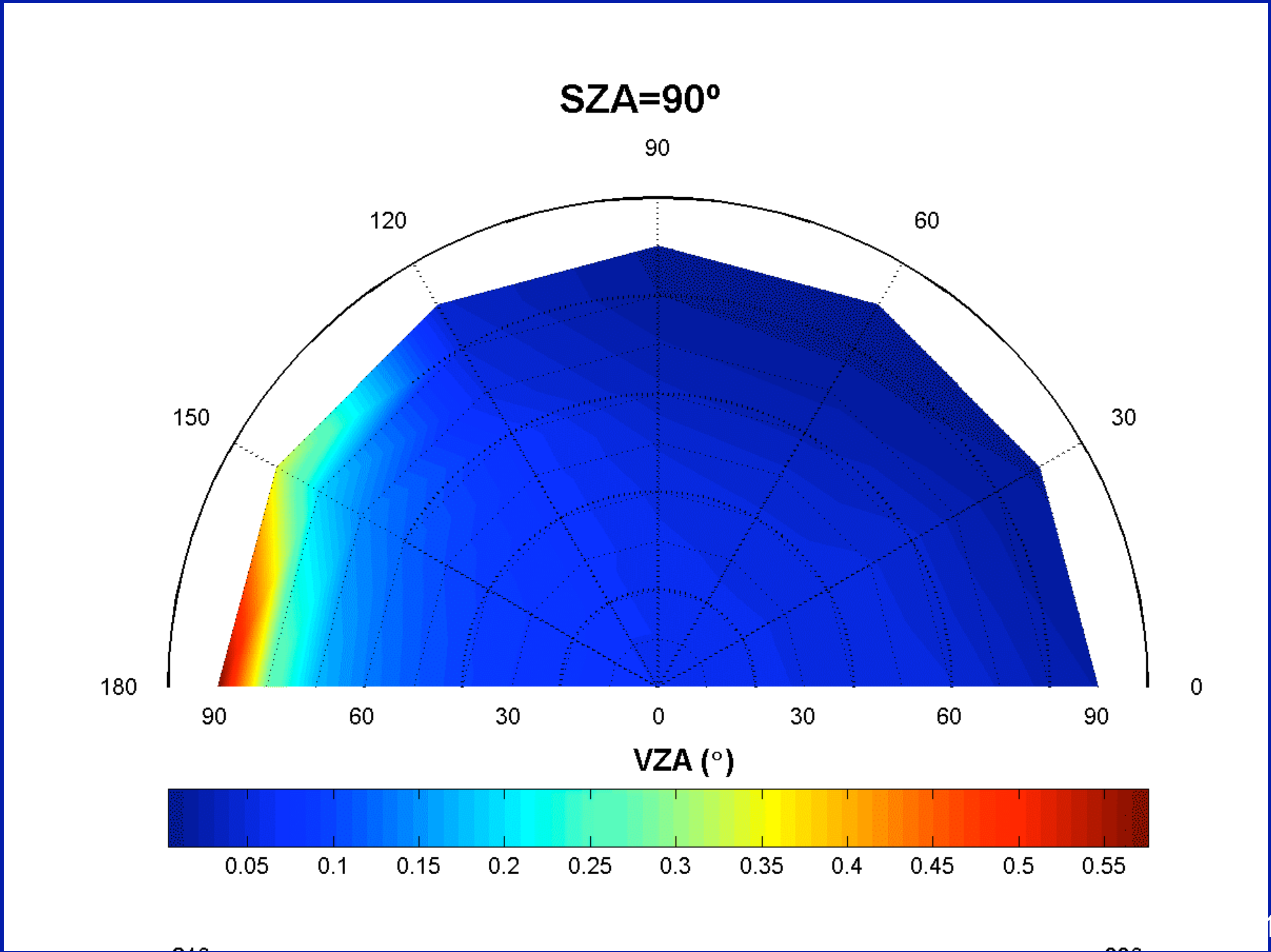
- **2. scale the bidirectional reflectances from the model**

$$s_{red} = \frac{a'_{\lambda red}}{\frac{1}{\pi}\int_0^{2\pi}\int_0^1 \rho_\lambda(\theta_0,\theta,\phi)\mu \cdot d\mu \cdot d\phi} = \frac{a'_{\lambda red}}{\rho_\lambda(\theta_0)}$$

$$s_{NIR} = \frac{a'_{\lambda NIR}}{\frac{1}{\pi}\int_0^{2\pi}\int_0^1 \rho_\lambda(\theta_0,\theta,\phi)\mu \cdot d\mu \cdot d\phi} = \frac{a'_{\lambda NIR}}{\rho_{\lambda NIR}(\theta_0)}$$

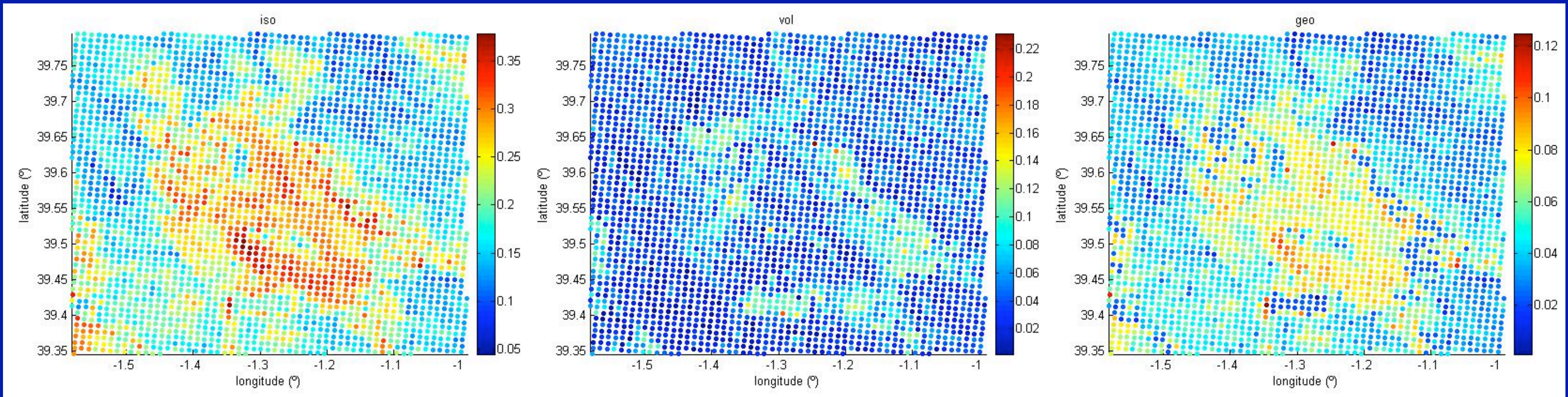


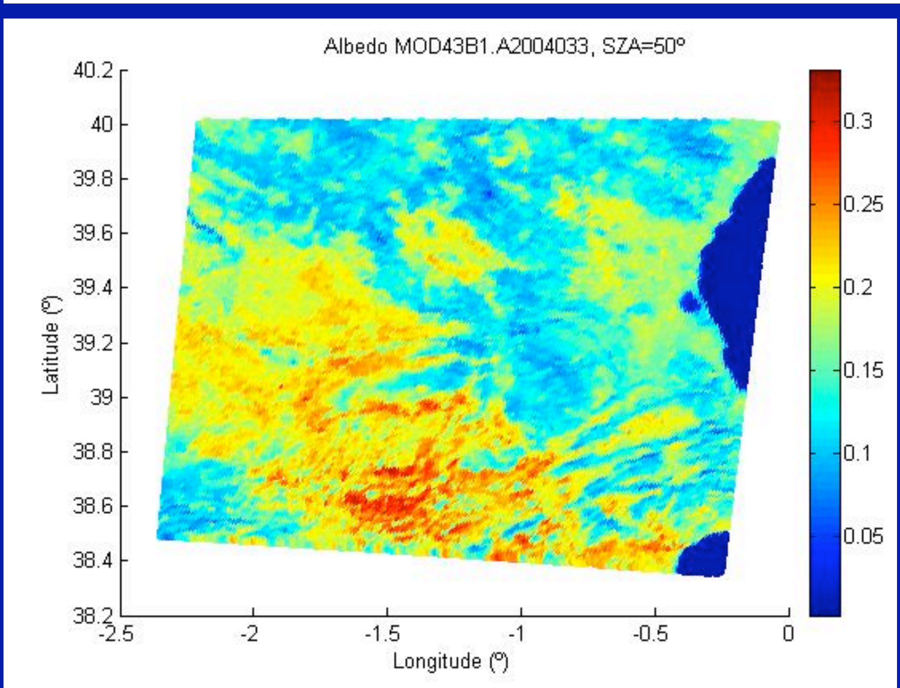
# Bidirectional reflectivity



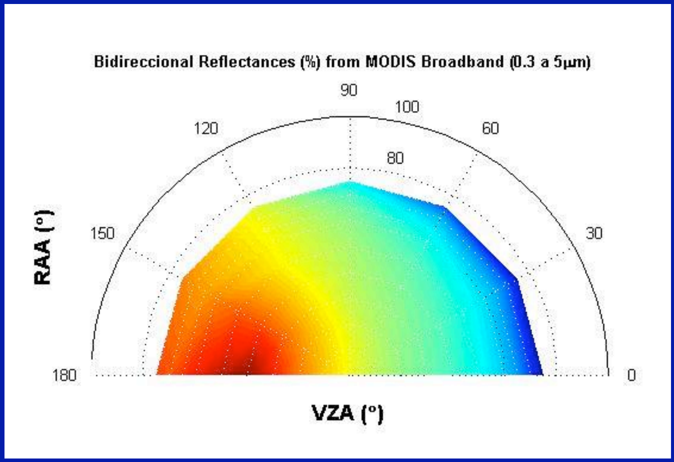
## 2) Method based on satellite observations

**BRDF:** **calculated from the isometric, volumetric and geometric Kernels of the MOD43B1 product for the Ross-Thick-Li-Sparse-Reciprocal model.**

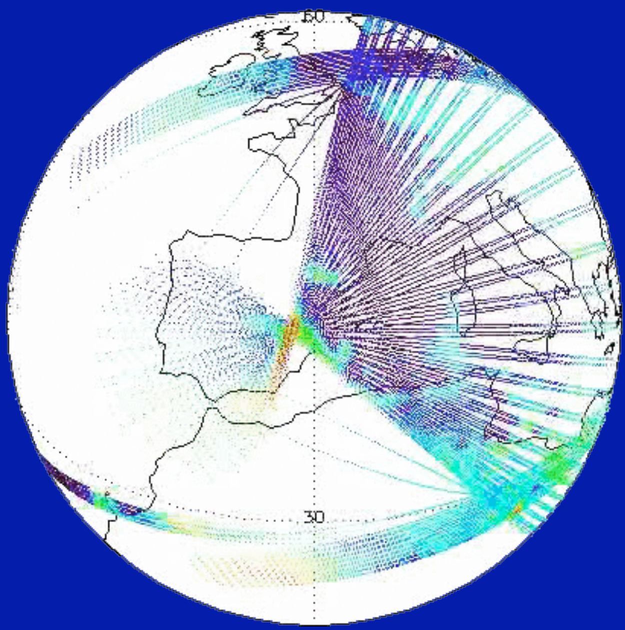



$$BRDF = k_0 + k_1 * f_{ross\text{-}thick} + k_2 * f_{li\text{-}sparse}$$

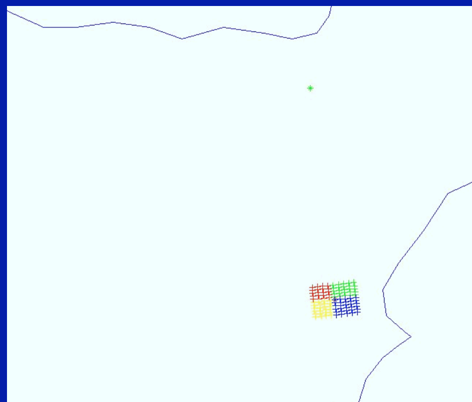


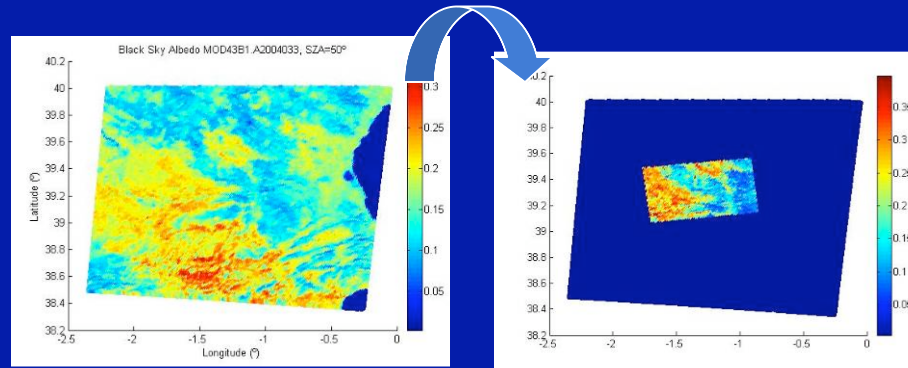
# ¿How to deal with the different spatial scales between CERES and MODIS?



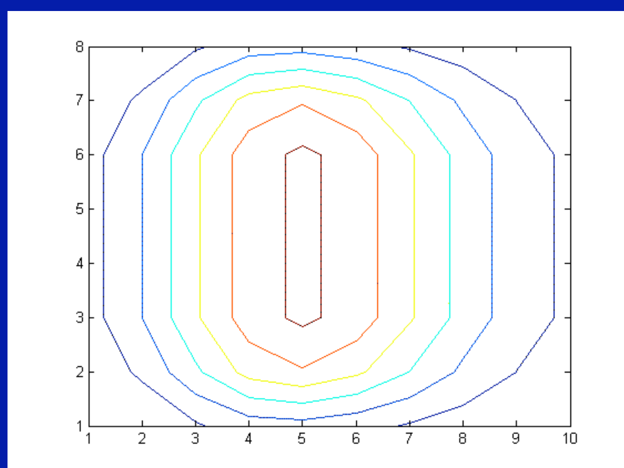

- CERES PAPS footprints vary in location and size from one to another.
- To know the BRDF at CERES scale it will be necessary to convolve the Imager Surface Properties with the CERES Footprint Point Spread Function

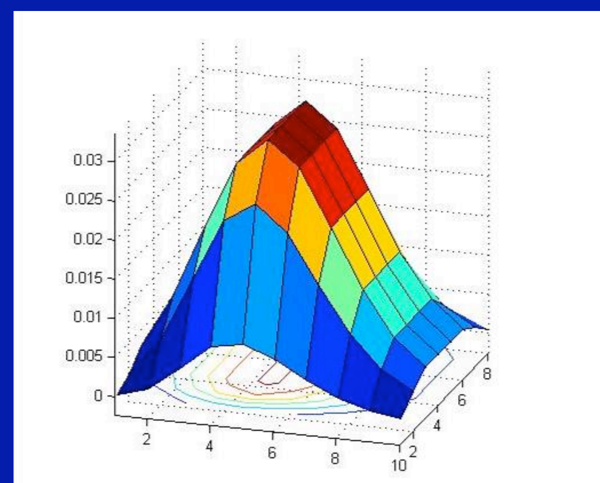
**First, we determine the limits of the CERES footprint and then we locate the pixels from MODIS that are within the CERES footprint.**






**The collocation algorithm must be able to handle with the shape of the footprints in PAPS mode and take into account the scanning direction because of the asymmetry of the CERES PSF.**





Note: The CERES FOV is a rectangular grid that approximates the 95% energy area with respect to the PSF

Then, we determine the statistics over the footprint with the surface properties from the HR imager data.

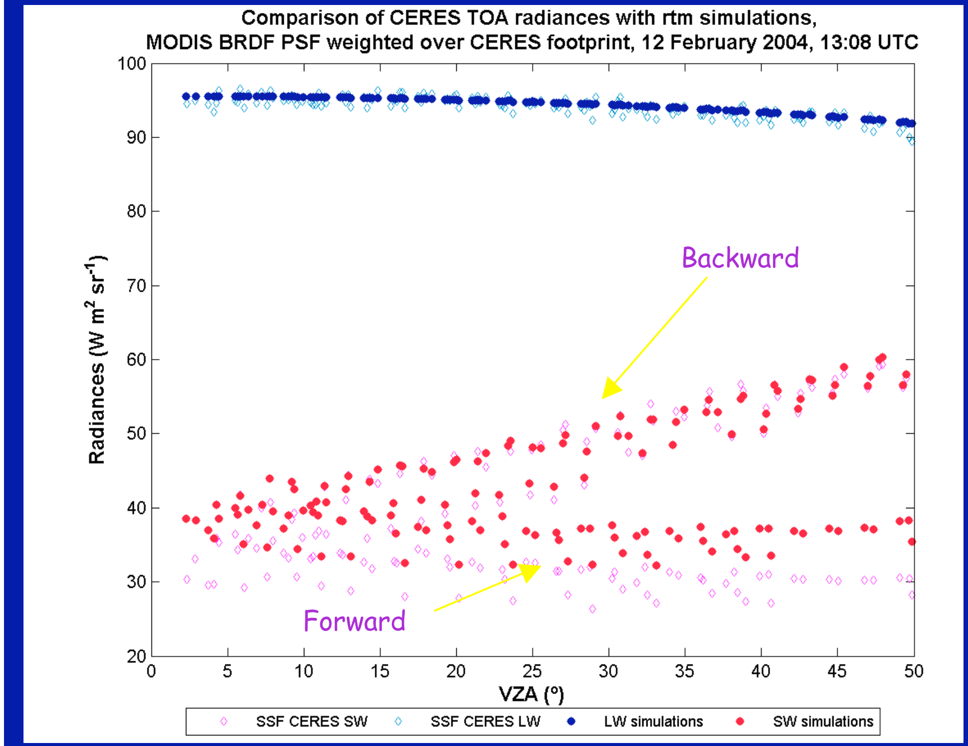
The results are the weighted means in which the weighting corresponds to the PSF.

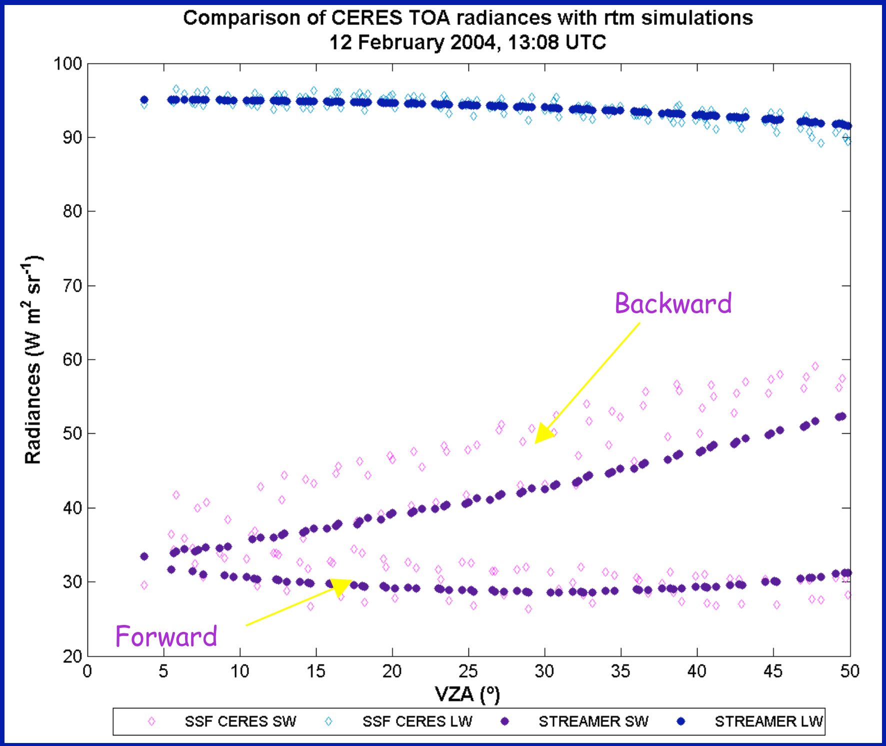
$$\bar{x} = \frac{\int_{FOV} P(\delta,\beta)\cdot x(\delta,\beta)\cos\delta\cdot d\beta\cdot d\delta}{\int_{FOV} P(\delta,\beta)\cdot\cos\delta\cdot d\beta\cdot d\delta}$$

$\delta$ and $\beta$ are the coordinates of a point in the FOV

Result: By applying the BRDF model to the weighted means of the parameters we obtain a BRDF for every CERES footprint and for the 7 MODIS narrowbands present in the MOD43 product, and for the 3 broadbands.

# 4. Results: Clear sky CERES TOA radiances simulation



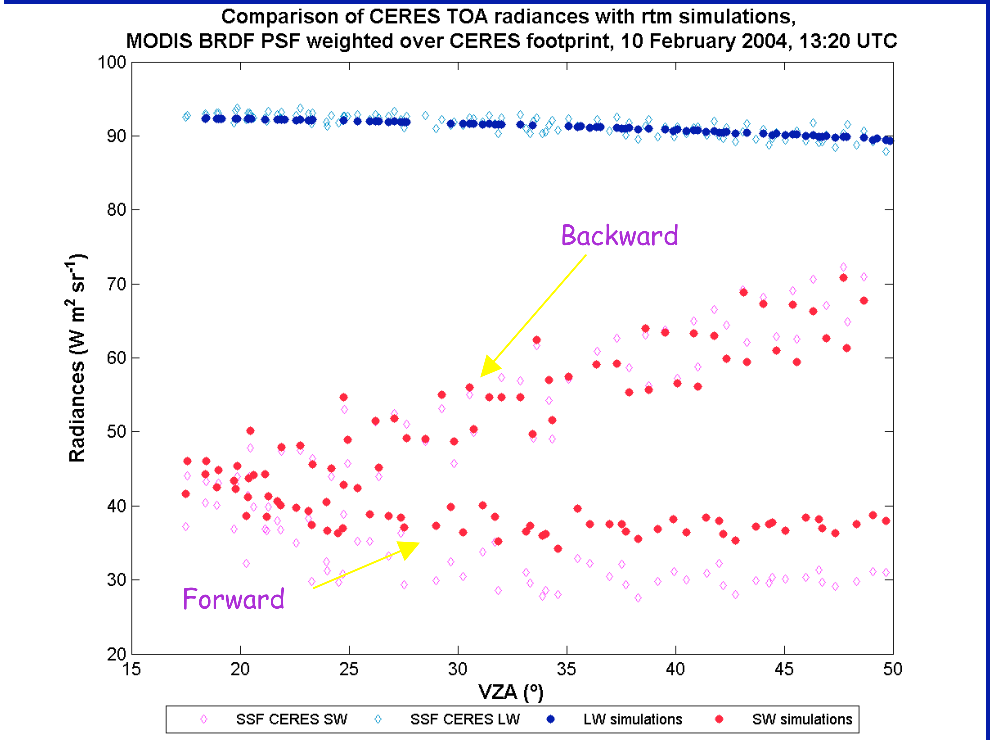



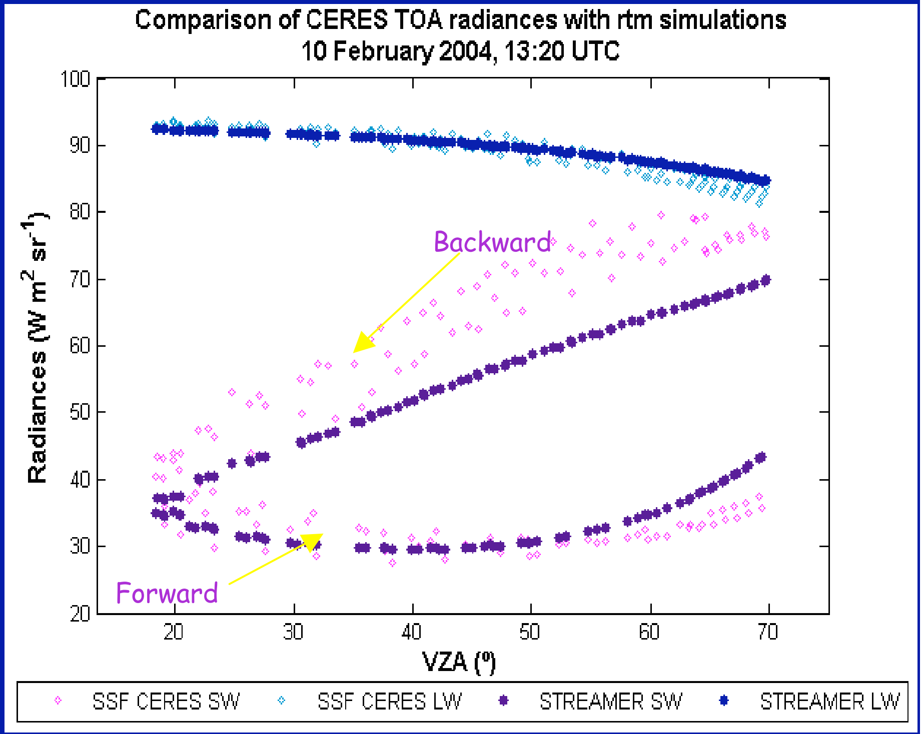

**RMSE_SW = 4.1 W m$^{-2}$ sr$^{-1}$**

**RMSE_LW = 0.8 W m$^{-2}$ sr$^{-1}$**

**RMSE_SW = 4.4 W m$^{-2}$ sr$^{-1}$**

**RMSE_LW = 0.8 W m$^{-2}$ sr$^{-1}$**



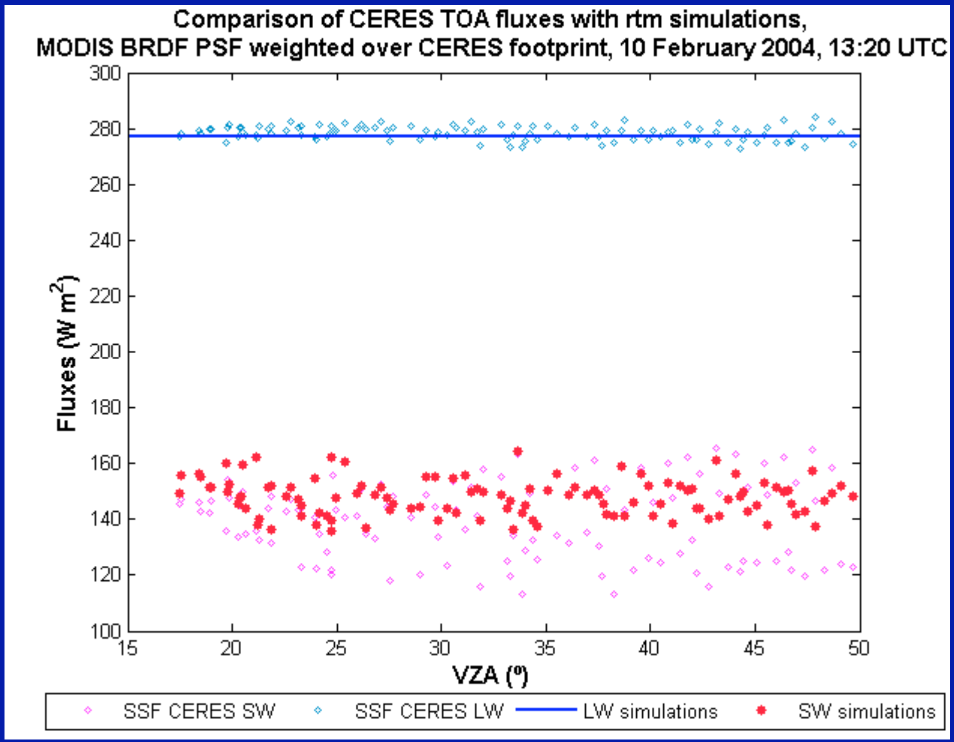

**RMSE_SW = 4.8 W m$^{-2}$ sr$^{-1}$**

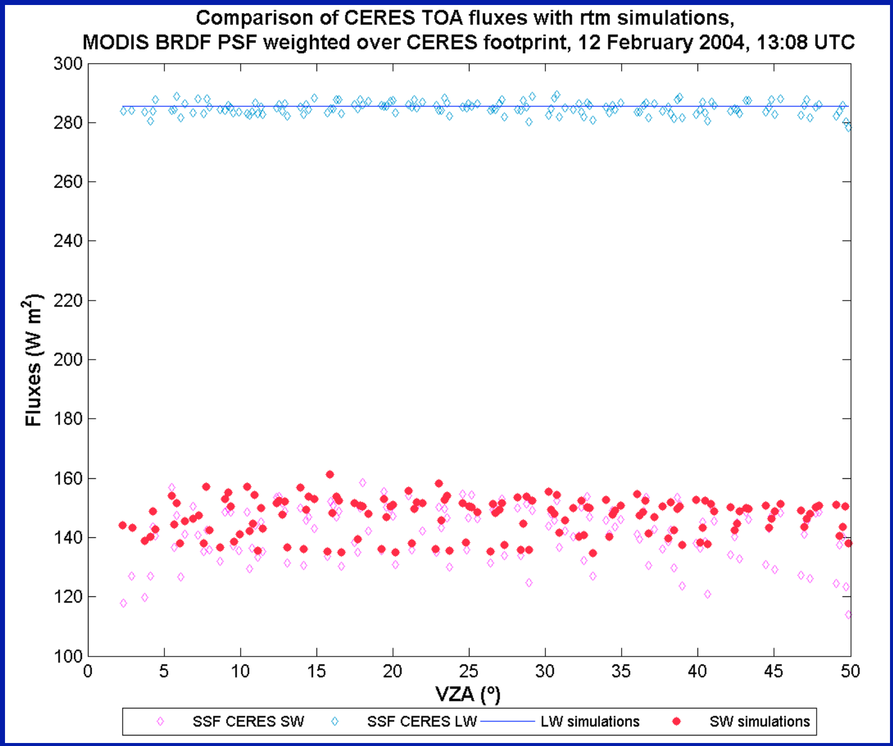
**RMSE_LW = 1.3 W m$^{-2}$ sr$^{-1}$**

**RMSE_SW = 7.6 W m$^{-2}$ sr$^{-1}$**

**RMSE_LW = 1.3 W m$^{-2}$ sr$^{-1}$**

# Clear sky CERES TOA fluxes simulation




**RMSE_SW = 14.9 W m$^{-2}$**

**RMSE_LW = 2.7 W m$^{-2}$**

**RMSE_SW = 8.6 W m$^{-2}$**

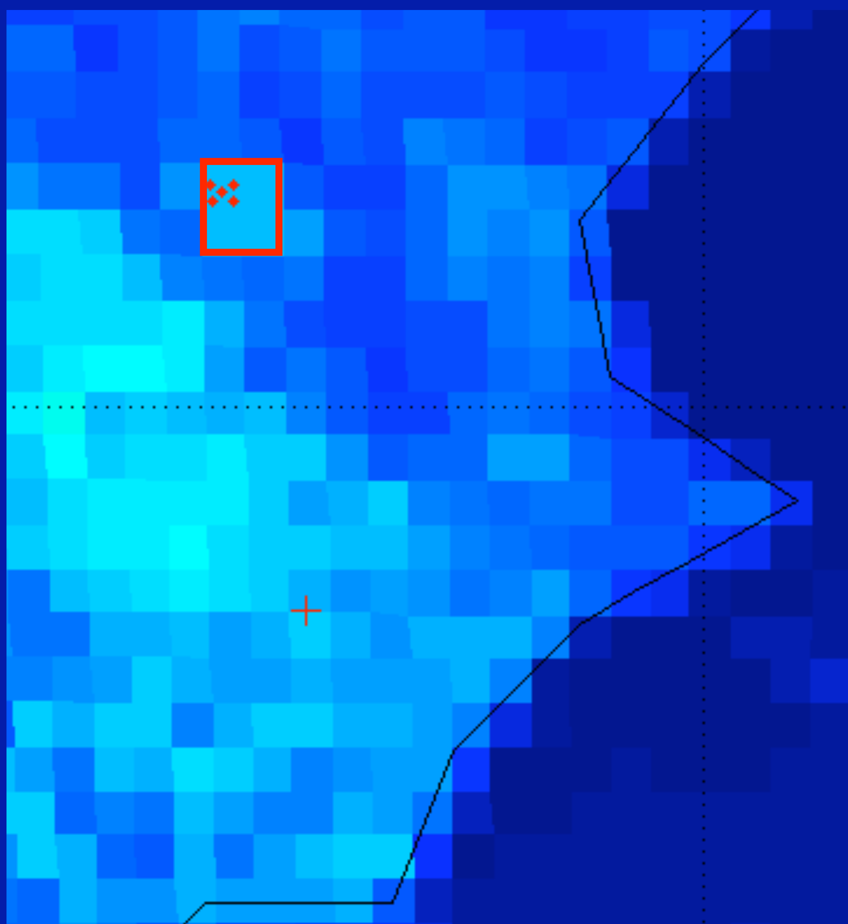
**RMSE_LW = 2.2 W m$^{-2}$**

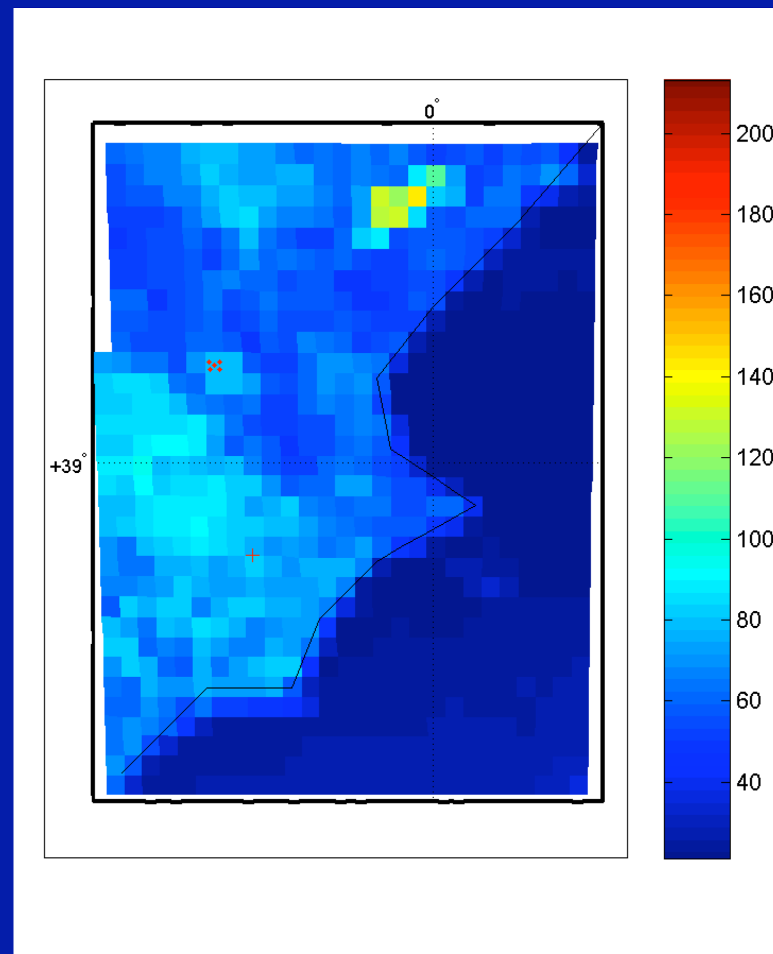
# GERB data used

G2_SEV1_L20_HR_SOL_TH_20060701.070000_V003.hdf

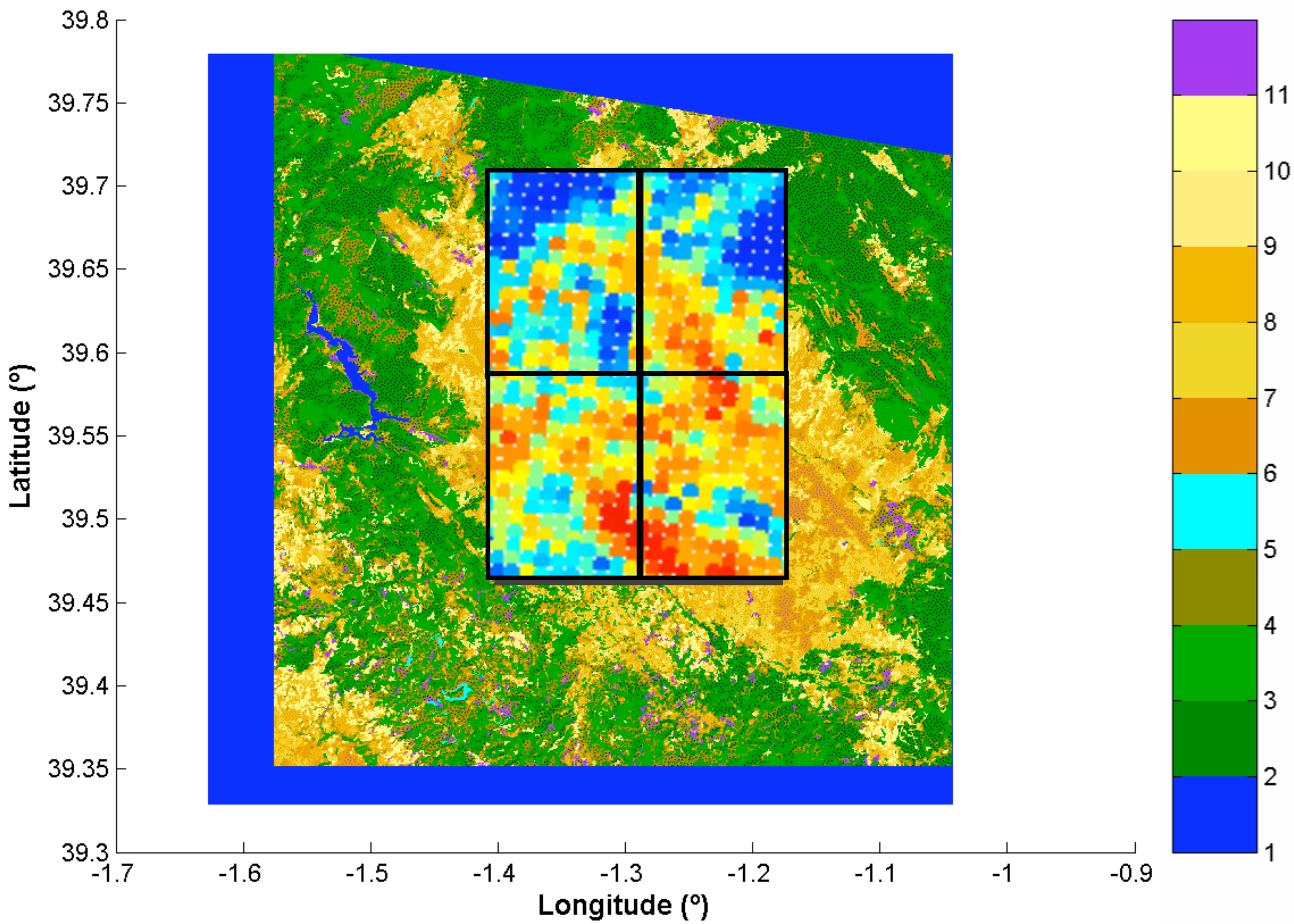
. . .

G2_SEV1_L20_HR_SOL_TH_20060701.170000_V003.hdf



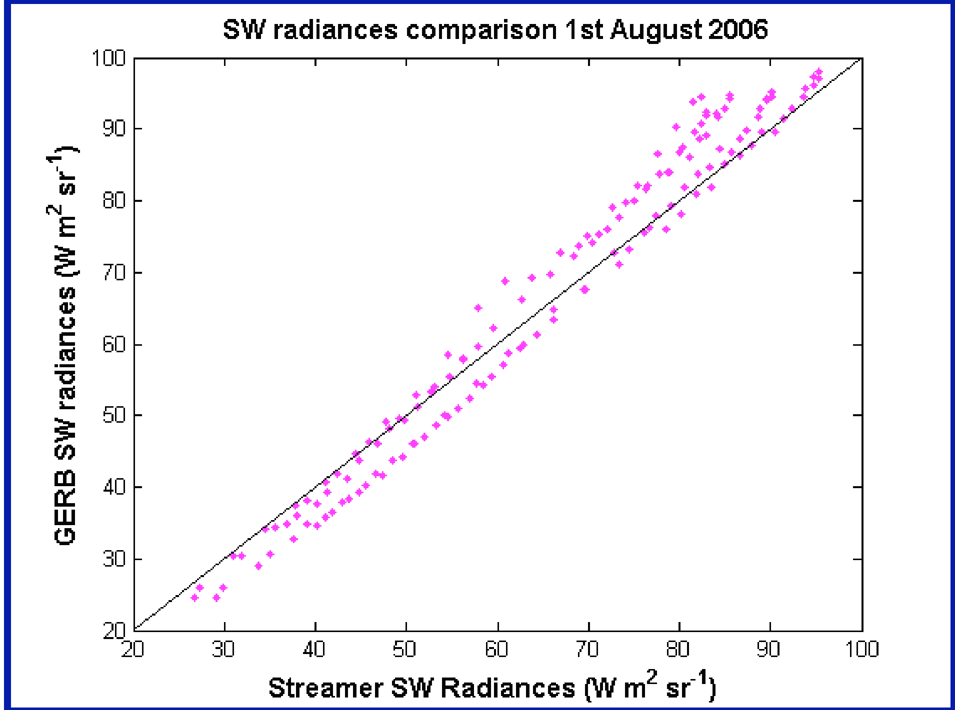


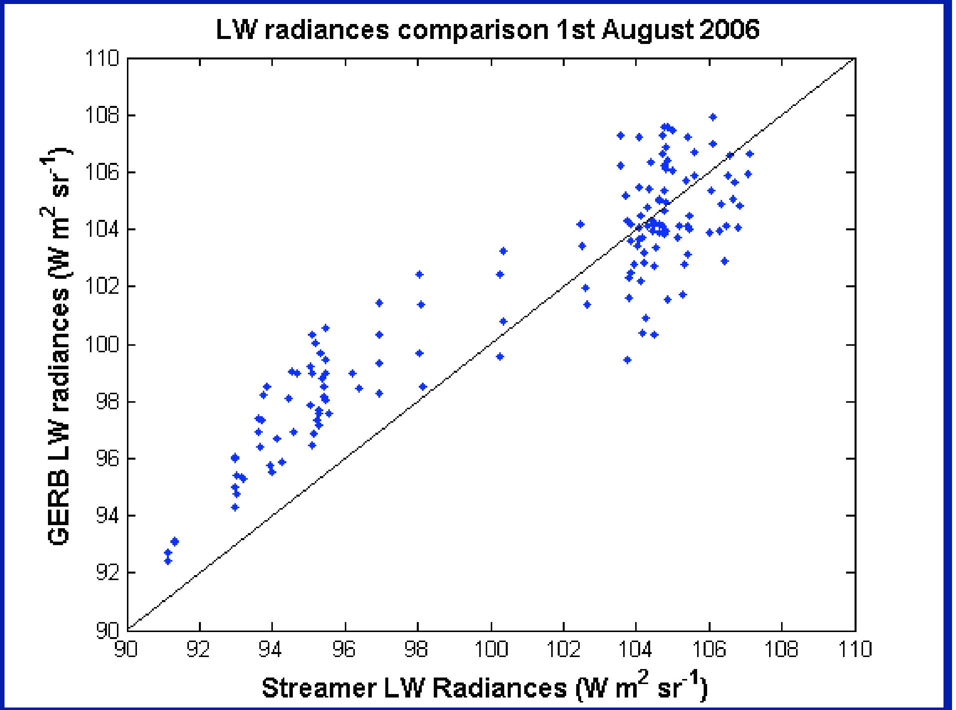
**For GERB comparisons, simulations have been done every 15 min, from 7:00 until 17:00 UTC, for the 1st of August 2006 over the 4 selected footprints that cover the study area. For GERB analysis, the type of data selected is independent of the PSF of the instrument, being just necessary to consider the dimensions of the footprints and average the kernels over them to obtain the pixels BRDFs.**




Land use classification for GERB pixels and MODIS data

# Clear sky GERB TOA radiances simulation

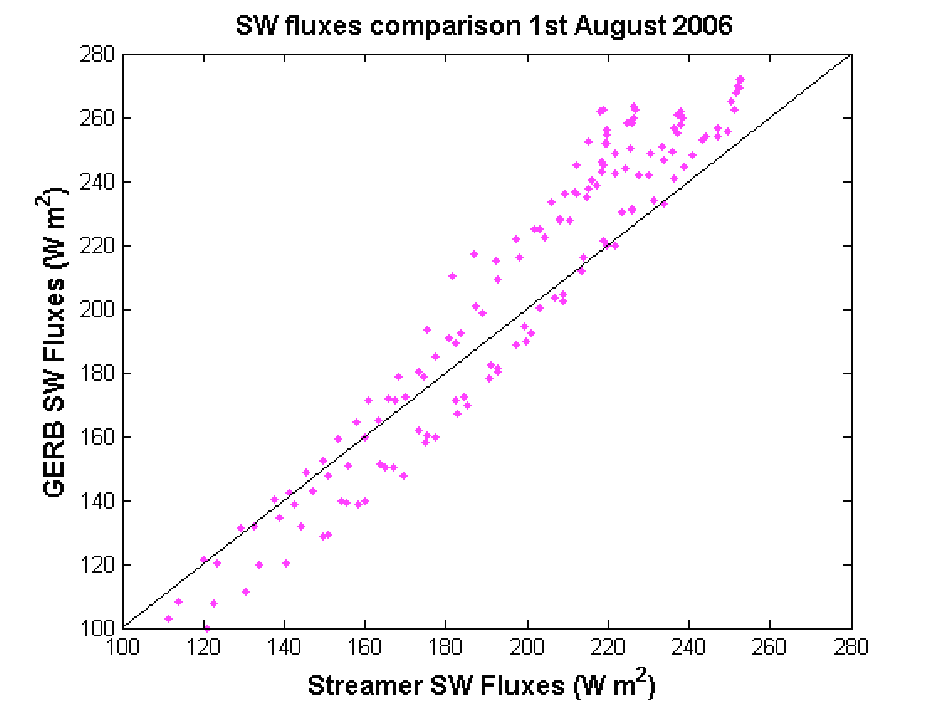


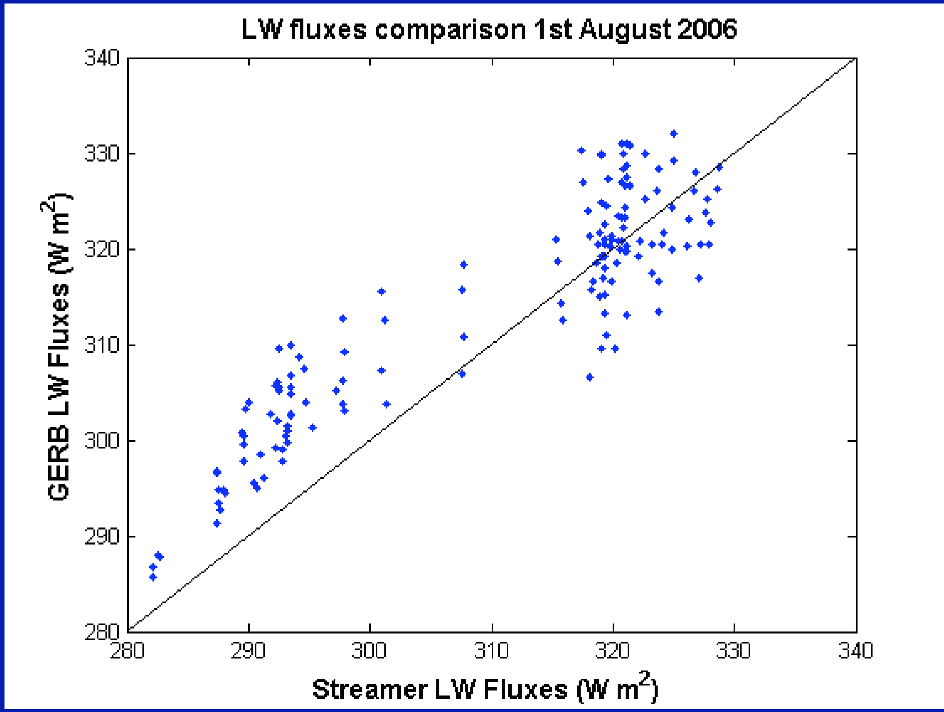




**RMSE_SW = 4.3 W $m^{-2}$ $sr^{-1}$**

**RMSE_SW = 2.3 W $m^{-2}$ $sr^{-1}$**

# Clear sky GERB TOA fluxes simulation



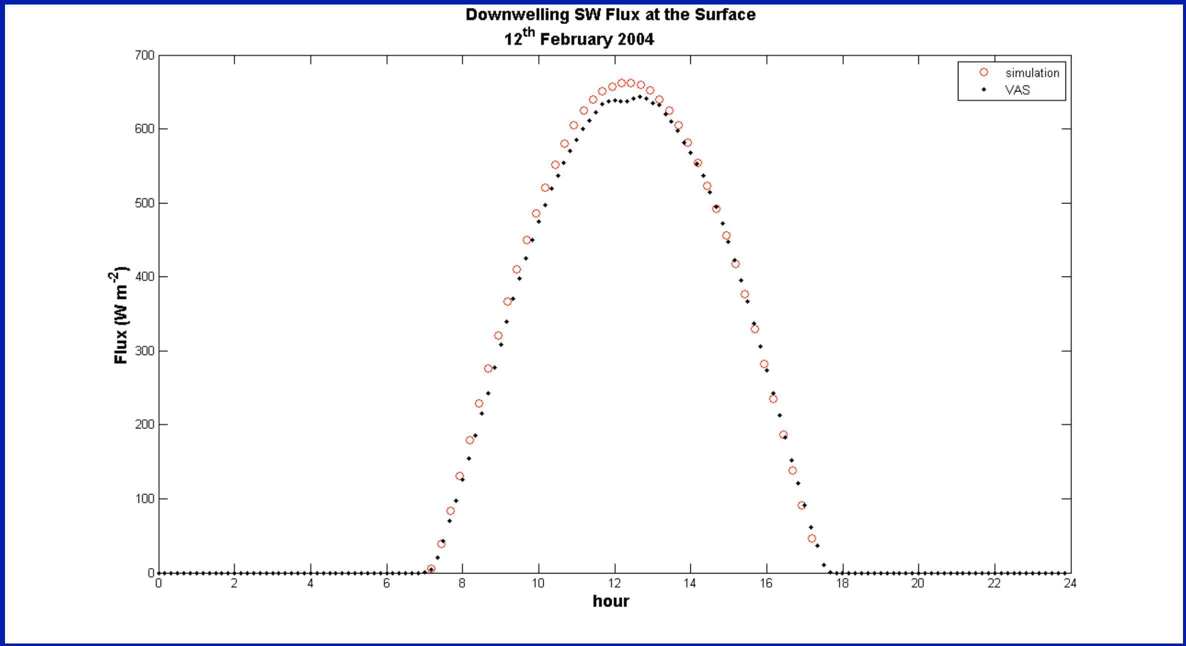




RMSE_F_SW = 17.5 W $m^{-2}$

RMSE_F_SW = 7.1 W $m^{-2}$

The comparisons between simulated and measured radiances and fluxes show good agreement, as well as in the CERES case. RMSE in SW radiances are of the same order as the obtained for CERES comparisons. In relation to the derived fluxes, GERB shows higher RMSE than CERES in the comparisons, needing this problem further investigations

# Preliminary Results of Surface comparisons

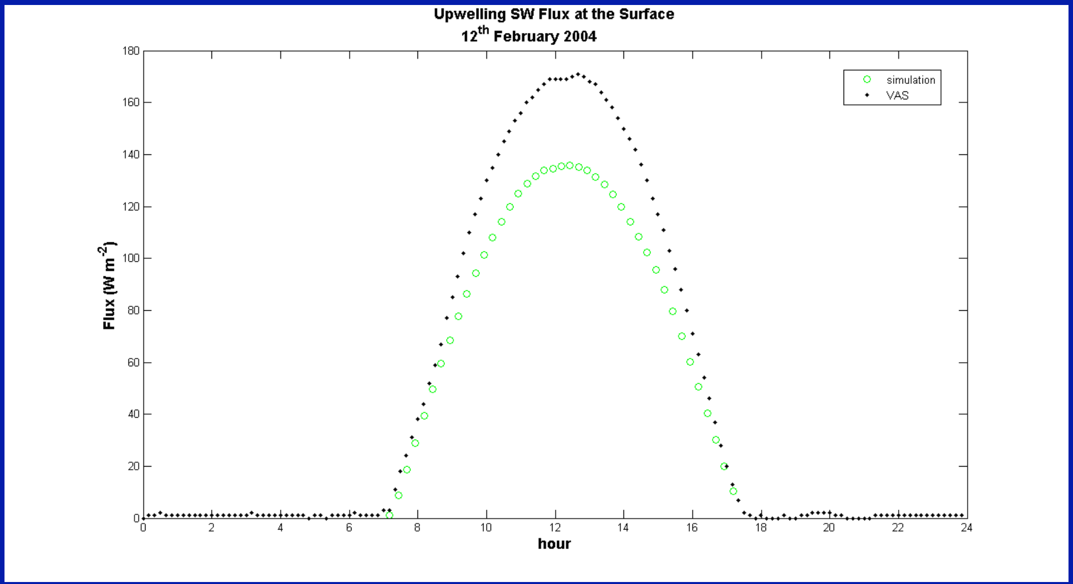



**RMSE_F_SW_down = 17 W m$^{-2}$**

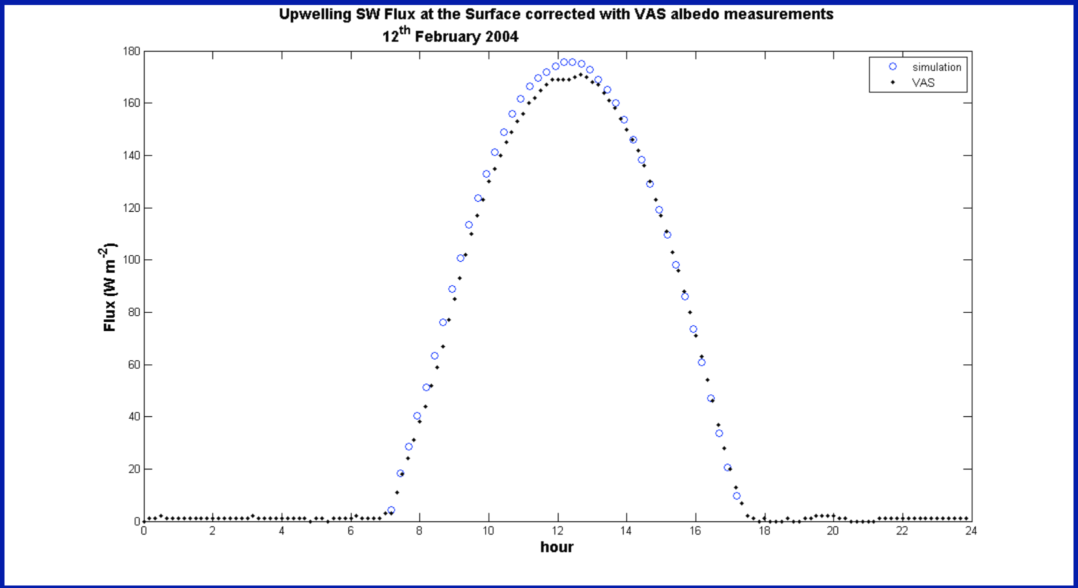
**For surface comparisons, simulations have been done every 15 min, from 7:00 until 17:00 UTC, for the 12 th of February 2004 over the Valencia Anchor Station.**

**Bidirectional reflectances are obtained from MODIS MOD43 product whose parameters are extracted over a 1 by 1 km$^2$ area around the Valencia Anchor Station**

As regards to upwelling sw flux, the comparison between simulated and measured fluxes shows high RMSE, due to the Bidirectional Reflectances we have used in the simulations, i.e, 1km around the station, that provide darker albedo than the measured in the station.

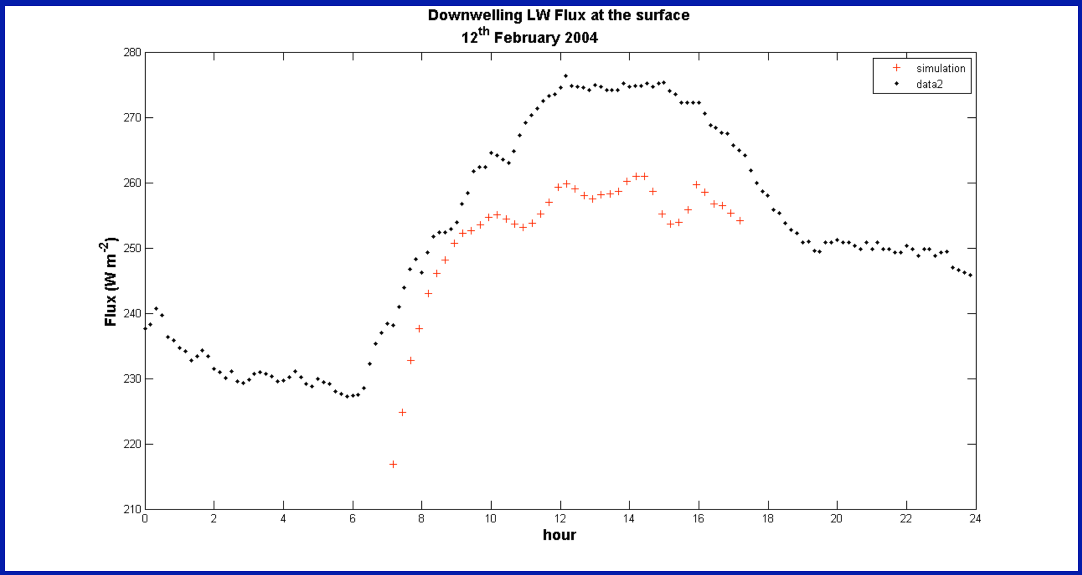



**RMSE_F_SW_up = 24 W m$^{-2}$**

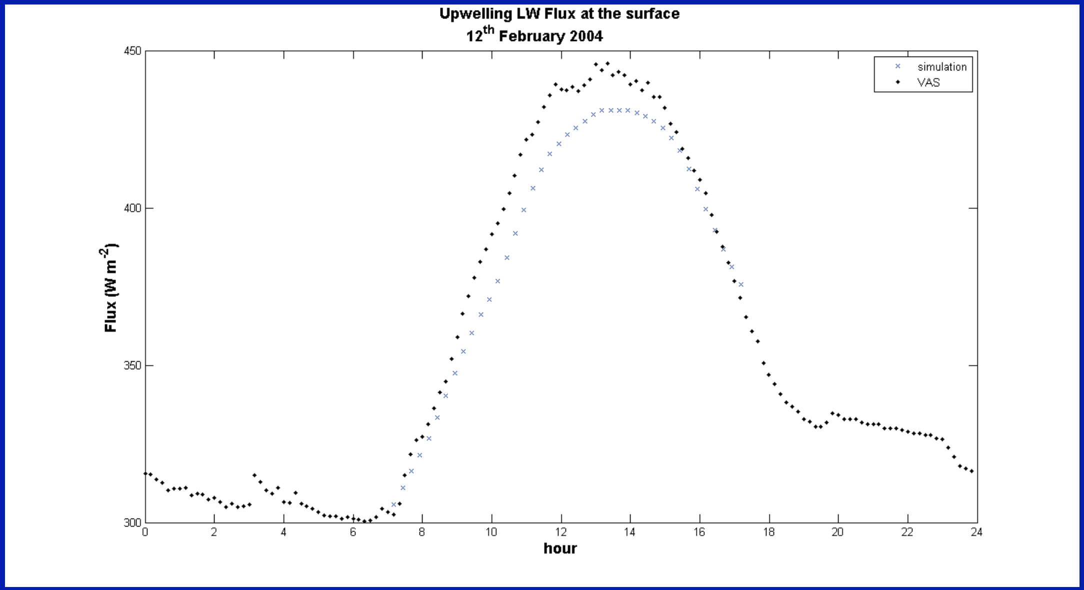



If we correct the bidirectional reflectances with the albedo measured in the station, the comparison makes more sense and RMSE is also reduced

**RMSE_F_SW_up_corrected = 5 W m$^{-2}$**




**RMSE_F_LW_down = 14 W m$^{-2}$**




**RMSE_F_LW_up = 12 W m$^{-2}$**

# 5. Conclusions

- The methodology here shown is able to reproduce CERES and GERB TOA unfiltered radiances and fluxes under clear sky conditions showing low RMSEs.

-

| SENSOR and date | RMSE for SW radiances ($W\ m^{-2} sr^{-1}$) | RMSE for LW radiances ($W\ m^{-2} sr^{-1}$) | RMSE for SW fluxes ($W\ m^{-2}$) | RMSE for LW fluxes ($W\ m^{-2}$) |
|---|---|---|---|---|
| **CERES SSF FM2** 12th Feb 2004 | 4.1 | 0.8 | 8.6 | 2.2 |
| **GERB High Resolution** 1st August 2006 | 4.3 | 2.3 | 17.5 | 7.1 |

- Simulated radiances finely reproduce the anisotropy of the radiance field at the TOA, being forward and backward features of TOA SW radiances well reflected in the results.

- The inclusion of a higher resolution BRDF in the methodology has significantly improved the comparison between simulated and measured fluxes and the global nature of the MODIS BRDF satellite data will allow further studies over wider areas

- CERES dedicated PAPS observations over the VAS are of great value to develop the methodology to validate low spatial resolution remote sensing data and products because of the large amount of angular information they provide.

- In this way, the methodology has been first assessed for CERES and then applied to GERB products. The comparison between simulations and CERES well calibrated and validated data provides a good indicator of the reliability of the methodology to be applied as a validation tool for GERB.

- Surface comparisons are still in a preliminary stage, but from them, it is easy to understand the importance of the bidirectional reflectance of the surface in validation tasks.

- Surface comparisons have been done only around the VAS, although it is planned to extend this study over wider areas to compare to the CERES SSF derived surface fluxes

# Acknowlegments

- A.Bodas, K. Priestley, W.Miller
- RMIB
- Spanish Institute of Meteorology